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ANTHROPOMETRIC COCKPIT COMPATIBILITY ASSESSMENT OF US ARMY AIRCRAFT FOR LARGE AND SMALL PERSONNEL WEARING A TRAINING, WARM-WEATHER CLOTHING CONFIGURATION

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20. ABSTRACT

To assess physical aviator-cockpit reach compatibilities, eight small subjects 146.9 to 162.5 cm in stature and eight tall subjects 182.3 to 194.5 cm in stature were placed in the cockpits of all current US Army helicopters (except AAH-64) and fixed-wing aircraft. Subjects were dressed in the warm weather training uniform of US Army aviators and were requested to operate all primary controls and instructor-pilot designated critical switches, knobs, etc., with the shoulder harness in the unlocked position. Helmeted head clearance also was evaluated.

Among several candidate measures of upper- and lower-body reach capabilities, total arm reach ("span"), and crotch height, respectively, were found to be the most efficient discriminators between those who could and those who could not perform all critical operational reaches. Sitting height was employed to assess helmeted head clearance.

Substantial variation was encountered in the reach-related demands for different aircraft. Minimum total arm-reach requirements throughout the fleet ranged from 147 to 168 cm; minimum crotch-height requirements ranged from 69 to 78 cm. Three aircraft could not accommodate a sitting height above 102 cm. Very large personnel experienced difficulty in achieving full lateral cyclic and stick movement in several aircraft.

PREFACE

This report is one of a series of reports on anthropometry in US Army Aviation produced by the US Army Aeromedical Research Laboratory (USAARL). Information on other reports in this series may be obtained by contacting the chief of the USAARL Scientific Information Center at AUTOVON 558-6907 or (205)255-6907.

Without the support of several personnel, this project would not have been possible. The authors would like to thank Headquarters, 1st Aviation Brigade, for their troop support coordination; the 46th Engineer Battalion, 1st Aviation Brigade, for providing a subject pool; the 46th Engineer Battalion personnel who volunteered their participation as subjects; Northrup Aviation Corporation, the Alabama Army National Guard, and the Alabama Army Reserve for providing aircraft; and the Aviation Logistics and Maintenance Division of the Directorate of Industrial Operations at Fort Rucker for providing hangar space.

Several people from USAARL aided in conducting this study. They include CPT George Mastroianni for his assistance in reducing the data, 2LT Robert McCaleb who reduced the data, SFC B.J. Clark, SSG David Wells and SSG Max Bass who aided in data collection, Mr. Lynn Alford for building some of the anthropometric apparatus, and Mr. Larry Thomas who photographed, developed, and printed thousands of photographic prints.

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INTRODUCTION

Previous evaluations of the feasibility of employing females in traditionally male military occupations have reflected the need for equipment redesign if women are to be effectively utilized. White and Desantis (1978) indicated that the anthropometric differences between males and females would necessitate substantial redesign of military equipment to enable women to function effectively. Ketcham-Weidl and Bittner's (1976) assessment of military aircraft was that considerable redesign would be required if a substantial portion of the female population were to be accommodated in military aircraft. However, as Glum (1976) suggests, much more information is required and much information is in need of updating regarding both female capabilities and the specific equipment/vehicle modifications required.

Prior to 1980, no empirical basis existed for the anthropometric standards required for Class 1, 1A, and 2 flying duty. The anthropometric standards in Army Regulation (AR) 40-501 (Department of Defense 1960) used for aviator training selections were predicated upon descriptive anthropometric studies of males and thus did not include data on females who became eligible for flight training in 1979. Moreover, the anthropometric studies previously undertaken by the Army (White 1977, 1979) do not provide information relevant to the problem being addressed. They have had greatest utility for the Quartermaster Corps since they were concerned with the design and manufacture of clothing. The continuing emphasis on clothing-related concerns is evident in the measures chosen for inclusion in bivariate frequency tables published by Churchill et al. (1977) and McConville et al. (1977). Bivariate distributions relevant to many combinations of reach-related measures are absent. The Army has not undertaken the types of descriptive anthropometric studies sponsored by the other services that emphasized more of the reach capabilities (Kennedy 1964, Thorsden, Kroemer, and Laubach 1972). Even Army-sponsored studies that have specifically addressed Army aviators (Churchill et al., 1971, and Shane, Littell, and Moultrie, 1969) have not emphasized reach capabilities.

Additional concerns exist regarding AR 40-501. These standards (prior to an interim change in 1980) were in conflict with the guidelines provided to aircraft designers and manufacturers in MIL-STD-1333A (Department of Defense 1976). AR 40-501 cited a range corresponding to the 5th to <u>99</u>th percentile male, whereas the guidance in MIL-STD-1333A utilized the 5th to <u>95</u>th percentile male as a referent.

Additionally, the standards contained in AR 40-501 effectively excluded a large percentage of the female population since the 5th percentile male stature corresponds to the 50th percentile female stature.

From the complementary perspective (i.e., that pertaining to actual cockpit measurements), the situation is little better. Albeit MIL-STD-1333A provides guidelines, there exist variations among aircraft. Linear cockpit-related reach information is unavailable from aircraft manufacturers, yet this information is essential for cockpit design. Shane and Slinde (1966) have compiled the only known cockpit reach-related information for Army aircraft. Although such information may have some relevance to a few of the older aircraft in the active Army inventory, most of it is outdated.

Without adequate human reach data and the designation of reach requirements critical to the safe and effective operation of present Army aircraft, selection criteria cannot be established and aviators cannot be matched with the aircraft that are compatible with their reach capabilities.

In response to requests from the Commanders of the US Army Aviation Center (ATZQ letter to The Surgeon General) and the Military Personnel Center (DAPC letter to the Surgeon General) to address these issues and provide a viable, empirical basis for the criteria cited in AR 40-501, The Surgeon General of the Army, through the US Army Medical Research and Development Command (DASG letter to USAMRDC, Nov 1979), tasked USAARL (USAMRDC letter to USAARL, Jan 1980) to reevaluate the anthropometric criteria for medical fitness standards for entrance into and retention in the US Army aviation program.

The initial study by Schopper (USAARL letter to USAMRDC, May 1980) resulted in the adoption of interim, revised minimum anthropometric criteria for reach-related dimensions. However, this brief study did not address maximum criteria and it did not include all rotary-wing aircraft in the active US Army inventory. Furthermore, neither fixed-wing aircraft nor aircraft unique to the US Army National Guard or the US Army Reserves were addressed.

The objective of the comprehensive research program subsequently undertaken (Schopper, 1982) was to establish a complete set of minimum and maximum linear anthropometric criteria and strength criteria for all Army aircraft. As regards linear anthropometric criteria, emphasis was placed upon identifying functional reach-related restrictions imposed by present aircraft cockpits.

METHODS

MATERIALS

All aircraft in the Army inventory, to include those used exclusively by reserve and national guard components, were evaluated. Aircraft in the active Army inventory were the TH-55A, OH-58C, UH-1H, UH-60A, CH-47C, AH-1S, T-42A, U-21A, C-12A, and the OV-1D. Aircraft in Army Reserve and Army National Guard units were the OH-6A, the CH-54A, and the U-8F.

SUBJECTS

Eight hundred potential subjects were screened to obtain a a reasonably uniform distribution of 1st to 5th and 95th to 99th percentile ranges for male upper and lower body reach capabilities.

Tall candidate subjects subjequently were screened for stature to attempt to obtain personnel in one centimeter increments from 182.9 cm to as tall an individual as could be identified. Short candidate subjects subsequently were screened by stature, crotch height, sitting height, and functional arm reach (see glossary, Appendix A, for definitions of body dimensions). Desired short subjects included those with statures below 162.7 cm, crotch heights between 69 cm and 75 cm, and a combined sitting height and functional arm reach from 150 cm to 156 cm. Once desired subjects were identified, they were asked to participate in the study. Some subjects who were willing to participate in the project were not allowed to because of conflicts with their unit's mission. However, subjects in the desired ranges were obtained. The anthropometric screening profiles of the 18 subjects (13 males and 5 females) who participated in the study are provided in Table 1.

TABLE 1

ANTHROPOMETRIC SCREENING PROFILE
OF SHORT AND TALL SUBJECTS

STATURE	SITTING HEIGHT	FUNCTIONAL ARM REACH	SITTING HEIGHT AND FUNCTIONAL ARM REACH	CROTCH HEIGHT	SUBJECT NUMBER
SHORT SUBJECTS:					
146.9	80.5	71.8	152.3	68.7	4
152.5	80.0	67.4	147.4	73.7	2
153.4	83.8	68.1	151.9	71.0	1
155.9	86.4	68.0	154.4	72.4	3
156.4	83.6	72.0	155.6	72.3	7
158.3	83.9	79.3	163.2	76.2	8
161.1	87.2	76.1	163.3	77.6	6
162.5	90.8	72.3	163.1	75.4	5
TALL SUBJECTS:					
182.3	98.8	82.1	180.9	84.8	9
183.9	96.1	81.0	177.1	93.0	11
184.1	90.8	83.6	174.4	93.7	10
186.3	98.7	82.2	180.9	89.2	13
186.5	99.6	81.0	180.6	89.8	14
189.0	96.0	87.7	183.7	96.1	15
189.5	96.0	87.1	183.1	93.4	16
192.4	100.6	84.2	184.8	93.4	18
192.5	97.3	89.5	186.8	96.0	17
194.5	102.8	92.1	194.9	92.2	19

NOTE: Measurements are expressed in centimeters.

PROCEDURE

Anthropometric Measurements

After the 18 subjects were selected, they were brought to the laboratory for further measurements to aid in identifying the critical anthropometric dimensions for each aircraft. These measurements are listed in Table 2 and described in the Glossary, Appendix A. The actual measurements obtained for each of these dimensions are provided in Appendix B.

TABLE 2

ANTHROPOMETRIC MEASURES OBTAINED FROM SUBJECTS

Body Dimension	Measurement Reference*
Weight	1C
Stature	2C
Sitting Height	11C
Seated Eye Height	12C
Functional Arm Reach	2W
Biacromial Breadth	16T
Shoulder Breadth	23C
Crotch Height	7C
Buttock-to-Knee Length	17C
Buttock-to-Heel Length	191**
Functional Leg Length	22***
Seated Hip Breadth	29***
Foot Length	62C
Upper Body Reach	See Text
Total Arm Reach ("span")	797**
Forward Body Reach	See Text

* With the exceptions cited, all references are to the measures described in Churchill *et al*. (1977).
** Churchill *et al*. (1978)
*** Churchill *et al*. (1971).

The study employed two nonstandard measurements. The first was a proposed measure of upper body reach (UBR) capability. UBR was obtained from the individual seated on a chair with the back plane at a right angle to the horizontal seat. A reference line was placed down the center of the two planes. The subject sat with the spinal column placed against the line on the vertical surface and the upper legs parallel to the line on the horizontal surface. The buttocks, shoulder blades, and back of the head touched the rear, vertical surface. The right arm was extended horizontally, parallel to the floor, and the thumb and index finger were pressed together as in the measure of functional arm reach (Churchill *et al*. 1977). The measurement was made from the point near the buttocks at which the vertical line on the back of the measurement chair intersected the forward/aft line on the seat of the chair, up and across the subject's back to the acromial notch of the right shoulder, along the upward surface of the arm to the end of the thumb. Figure 1 shows the UBR measure.

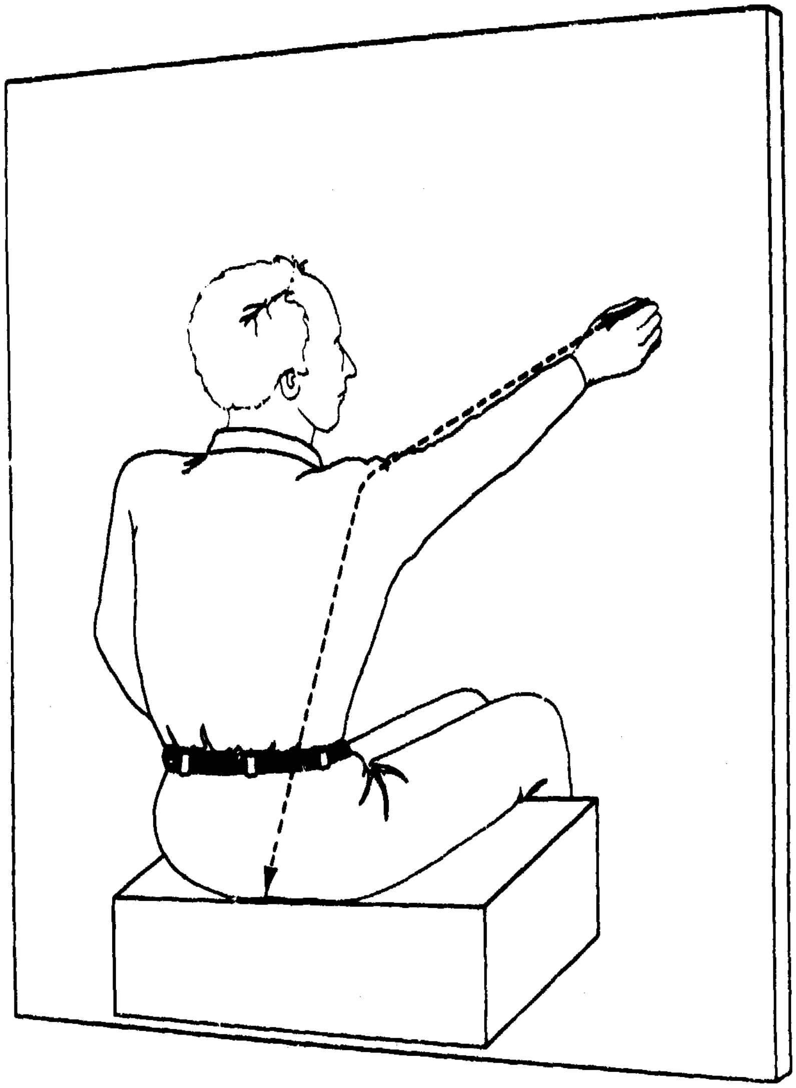

FIGURE 1. Upper Body Reach.

The second nonstandard measurement was that of forward body reach. Forward body reach was measured in a horizontal reference plane 72.4 cm above the floor. The subject was seated 52.7 cm above the floor. Reaches were obtained separately for each arm. Each measurement was obtained with the forward extension in the midsagittal plane of the subject. The referent origin corresponded to the point resulting from the intersection of the vertical back plane of the anthropometric measuring device, the horizontal reference plane, and the midsagittal plane of the normally-seated subject. The subject was instructed to reach as far as

possible while keeping the buttocks in firm contact with the seat and back of the anthropometric measurement device (Figure 2). A wooden dowel 15 cm high was placed within 2 cm of the front of the center of the crotch to ensure that the subject did not slide forward on the seat. A researcher also visibly inspected the subjects during their reaches to insure that they kept their buttocks in contact with the seat and the back of the device.

FIGURE 2. Forward Body Reach.

The measure of forward body reach was taken from the above-described reference point on the seat back to the tip of their middle finger. The average of the left and right forward reaches for each subject was computed and is reported in Appendix B.

Critical Reaches

The assessment of compatibility of a subject with a cockpit was based upon a set of critical reaches established by instructor pilots for each aircraft at the US Army

TABLE 3

OPERATIONAL ASSESSMENT CRITERIA FOR PRIMARY CONTROLS AND CRITICAL ANCILLARY CONTROLS

Controls	Criteria
Cyclic	1. Wrap right hand firmly around the cyclic in the full forward position such that full contact exists between the cyclic grip and the palm of the hand.
	2. Move the cyclic to its full forward, aft, and lateral positions.
Yoke	1. Wrap both hands firmly around the yoke in the full forward and full aft positions so that full contact exists between the yoke handles and the palm of the hands.
	2. Rotate the yoke to the full clockwise and counterclockwise positions.
Collective	1. Wrap left hand firmly around the collective in the full down position so that full contact exists between the throttle and the palm of the hand.
Pedals*	1. Place ball of right foot on the middle of the right pedal surface with the right pedal in the full forward position without sliding forward in the seat.
	2. Place ball of left foot on the middle of the left pedal surface with the left pedal in the full forward position without sliding forward in the seat.
	3. Place ball of right foot on the middle of the right pedal surface, ball of left foot on the middle of the left pedal surface, and boot heels resting comfortably on the heel pan or floor (dependent on the aircraft) with the pedals at the center of their range of travel.
	4. Maintain the balls of both feet on the centered pedals (as in 3 above) while simultaneously obtaining a firm grasp of the collective in its full down position (as described in "collective" above) and moving the cyclic through the range of motion.
Critical Ancillary Controls	1. Reach and operate.

* Pedals were initially adjusted pairwise to either the extreme forward position (for tall subjects) or the extreme aft position (for short subjects) prior to assessing the reach capability of each subject.

Aviation Center, Fort Rucker, Alabama . These critical reaches included all three primary controls (i.e., the cyclic, collective, and pedals), and all switches, dials, knobs, etc., (hereafter referred to as "ancillary controls"), that instructor pilots judged to be critical to fly the aircraft in any conceivable flight situation, including emergencies. Then, criteria were established for each of the critical reaches. The critical reaches and their criteria are outlined in Table 3.

A complete listing of all critical ancillary controls is given in Appendix C. Subject-cockpit incompatibilities were recorded in writing and pictorially documented.

Preparation of Aircraft

The preparation of an aircraft for data collection varied depending on the aircraft. Some aircraft had to have doors removed so that the subjects could be photographed in the cockpit, some had to have control linkages disconnected so the controls could be operated without the need for external power, and others that didn't permit easy control linkage disconnection had to have external power so the controls could be operated. No jacks or towing devices were allowed to stay on the aircraft when they were prepared for data collection or while data was being collected. Critical points in the cockpit were identified with white tape.

The seat in each aircraft, when adjustable, was positioned to accommodate the short and tall subjects. For short subjects, the seat was raised as high as it would adjust in the vertical direction and moved as far forward as it would adjust in the horizontal direction. When tall subjects were placed in the cockpit, the seat was lowered to its lowest vertical adjustment and moved as far back as it would adjust in the horizontal direction. For the one aircraft with a tilt adjustment, the CH-47C, the seat was tilted maximally upward and forward for the short subjects and maximally downward and rearward for the tall subjects. Table 4 contains the pilot seat adjustment capabilities for each aircraft.

TABLE 4

AIRCRAFT SEAT ADJUSTMENT CAPABILITIES

AIRCRAFT	ADJUSTMENT DIRECTION Fore/Aft	Up/Down	Tilt
TH-55A*			
OH-6A*			
OH-58C*			
UH-1H	X	X	
UH-60A	X	X	
CH-47C	X	X	X
CH-54A	X	X	
AH-1S(pilot)		X	
AH-1S(copilot)*			
T-42A	X		
U-8F	X	X	
U-21A	X	X	
C-12A	X	X	
OV-1D		X	

* Seat does not adjust.

The pedals also were adjusted manually for the two groups of subjects. Pedals were adjusted pairwise to the full aft position for short subjects and to the full forward position for tall subjects.

Critical Reach Measurement

Subjects were placed in the pilot's seat of each aircraft and in both the pilot's and copilot's seats of the AH-1S. They wore the one-piece flight suit and a fully-equipped tropical survival vest (NSN 8465-00-1174-819). A .38 caliber

pistol in a holster was worn on the left side of the vest. After the subjects were securely fastened in the seat by tightening the seat belt, they were instructed to: Move the cyclic to its full forward, full aft, full left and full right positions; push the collective to its most extreme downward position; push the left pedal with the ball of the left foot to its full forward position; push the right pedal with the ball of the right foot to its full forward position; and operate all critical ancillary controls (e.g., switches, knobs, reset buttons, etc.). In fixed-wing aircraft with yokes, they were instructed to move the yoke to the full forward and aft positions and rotate it to the extreme clockwise and counterclockwise positions.

The shoulder harness was employed in the unlocked position as reflected in the guidance in the aviators' operator manuals. Subjects were not allowed to slide forward in their seats to obtain full pedal. Their buttocks were to remain in contact with the seat back and seat pan. When critical reaches could not be attained, they were annotated on a data collection sheet.

Data Analysis

Success or failure to reach primary and/or critical ancillary controls were coded separately for each subject in each aircraft. Then, these data were used in conjunction with the anthropometric data available for each subject. Pass/fail information pertaining to hand-operated controls was used in conjunction with each of the listings of subjects which resulted from rank ordering (from smallest to largest) all individuals according to their stature, functional arm reach, combined functional arm reach plus sitting height, upper body reach, average forward reach, total arm reach, and combined total arm reach plus sitting height. Similarly, pass/fail information pertaining to foot-operated controls was combined with separately generated rank-order listings of stature, functional leg length, buttock-to-heel length, and crotch height.

Once these pass/fail annotated, rank-ordered lists were generated for all aircraft, each was examined to determine a "critical value." The critical minimum value of a rank-ordered listing of subjects along a particular dimension for a specific aircraft was the value immediately above (i.e., larger than) the value at which a failure was observed. Ideally, all values smaller than the critical value would be

those associated with subjects who were unable to perform the critical reaches. Likewise, all values equal to or larger than the critical value of an ideal dimension would correspond to those individuals who were able to perform the critical reaches. Unfortunately, the dimensions did not yield such an ideal circumstance. Misclassifications did occur; i.e., rank-order listings did result wherein there were values less than the "critical value" which corresponded to individuals who could, in fact, perform the critical reach satisfactorily.

In the interest of simplicity and parsimony, an analysis was undertaken to determine the "efficiency" of the various candidate measures associated with hand-operated controls and foot-operated controls. In the present context, "efficiency" was defined as that measure (or combination of measures) which yielded the fewest "misclassifications." Operationally, this determination entailed assembling the pass/fail-coded, rank-order listings of each measure for all aircraft and tabulating the total number of misclassifications associated with it. The most efficient measure was that which resulted in the fewest number of misclassifications.

RESULTS

The results of the overall cockpit compatibility evaluation are provided in Table 5. Included in it are the critical values for the most efficient reach-related dimensions (total arm reach and crotch height) and for the dimension employed to evaluate head-to-ceiling compatibility (sitting height). Among the seven aircraft wherein the range of small-sized subjects encompassed the critical value, total arm reach (TAR) was clearly superior to any other dimension or combination of dimensions in its ability to efficiently discriminate between those who could and those who could not reach and operate all hand-operated controls and critical ancillary controls. Among the remaining six aircraft, no hand-operated critical reach problems were encountered in four of them (AH-1S, C-12A, OV-1D, T-42A). In the other two aircraft (CH-47C, U-8F), none of the short subjects could perform all critical reaches.

TABLE 5

SUMMARY OF CRITICAL AVIATOR DIMENSIONS
FOR
US ARMY AIRCRAFT

AIRCRAFT	MINIMUM TOTAL ARM REACH (cm)	MINIMUM CROTCH HEIGHT (cm)	MAXIMUM SITTING HEIGHT (cm)
ROTARY WING:			
TH-55A Trainer Helicopter	153	73	102*
OH-6A Observation Helicopter	150	71	99
OH-58C Observation Helicopter	150	74	97
UH-1H Utility Helicopter	163	75	102**
UH-60A Utility Helicopter	153	69*	102**
CH-47C Cargo Helicopter	165	69*	102**
CH-54A Cargo Helicopter	153	69*	102**
AH-1S Attack Helicopter	147*	76	102**
FIXED WING:			
T-42A Training Airplane	147*	71	96
U-8F Utility Airplane	168	78	102**
U-21A Utility Airplane	160	76	102**
C-12A Cargo Airplane	147*	74	102**
OV-1D Observation Airplane	147*	75	102**

* No critical measurement observed, all subjects were able to attain the critical reach; the measurement cited is that of the subject with the shortest total arm reach or crotch height evaluated in the aircraft.
** No critical head-clearance problems encountered; the value cited is that of the largest sitting height measured among the subjects participating in the study.

The TAR measure was the most efficient measure of upper-body reach capability. Among those nine aircraft wherein upper body reach problems were evidenced, only two misclassifications were encountered with the TAR measure, one in the UH-1H and one in the U-21A. The next two most efficient dimensions were stature and the combinations of TAR with sitting height (TARSH). Both resulted in a total of five misclassifications involving four aircraft for stature and five for TARSH. Functional arm reach (FAR) and its combination with sitting height (FARSH) were ranked third in efficiency, each resulting in nine misclassifications involving five and seven aircraft, respectively. The two most inefficient measures were the upper body reach (UBR) and the average forward reach (AFR). They resulted in 11 and 16 misclassifications, respectively. UBR misclassifications involved five aircraft and AFR misclassifications involved seven.

The same analyses applied to the dimensions used to evaluate lower-body reach compatibility with foot-operated controls revealed crotch height to be the superior. Among the 10 aircraft addressed where foot-operated control reach-related problems were encountered (none were found in the CH-47C, CH-54A, and the UH-60A), the crotch height dimension resulted in only one misclassification. Second in discriminatory efficiency was the functional leg-length dimension. It resulted in four misclassifications involving two aircraft. The figures for the remaining two dimensions were five misclassifications involving three aircraft for stature and seven misclassifications involving five aircraft for buttock-to-heel length.

DISCUSSION

HELICOPTERS

In the TH-55A training helicopter, short subjects with a total arm reach less than 153 cm could not reach and tune the altimeter. The other problem short personnel experienced in the TH-55A was not being able to input full pedal. A minimum crotch height of 73 cm discriminated between those who could input full pedal and those who could not. No head-clearance problems were encountered. All but two tall subjects were unable to achieve full lateral cyclic movement because the cyclic hit their legs.

The OH-6A presented the same types of problems to personnel as the TH-55A. Short personnel with a total arm reach less than 150 cm could not operate the radio control knobs of the FM radio located on the upper left portion of the instrument panel. Some short personnel also could not input full pedal. A crotch height of 71 cm differentiated them from those who could input full pedal in the OH-6A. One tall individual (subject 17) could not input full right cyclic in the OH-6A because there was inadequate lateral space in the cockpit. Helmeted individuals with a sitting height of 99 cm or more did not have adequate head room.

The OH-58C presented the same problems to short subjects as the previous two aircraft. Short personnel with a total arm reach <150 cm could not operate the controls of the UHF-AM radio under the transponder on the left side of the instrument panel. Some short personnel also could not input full pedal. Only personnel with a crotch height ≥ 74 cm could input full pedal in the OH-58C. One tall subject, subject 17, was unable to input full lateral cyclic in the OH-58C. Many tall personnel could not sit in a comfortable position due to insufficient head clearance. As illustrated in Figure 3, helmeted personnel whose sitting height was ≥ 97 cm were forced to lean forward to sit in this cockpit.

In the UH-1H, short personnel did not have any difficulty reaching all critical overhead and instrument panel switches, dials, controls, etc. However, other problems were encountered. Short personnel whose crotch height <75 cm could not input full pedal. Another problem short personnel had in the UH-1H was not being able to maintain the balls of their feet on the pedals when attempting to obtain a firm grasp of the collective in the full down position. Many personnel had to lean down towards the collective, thereby keeping only the toe of their right boot on the right pedal. Those with a total arm reach of 163 cm and a crotch height of 75 cm could

FIGURE 3. Tall Subject in an OH-58C; Helmet is in Contact With Ceiling of Cockpit.

accomplish this task successfully. The problems of not being able to input full pedal and not being able to input full down collective without changing pedal foot position could be eliminated by lowering the seat from the full up position for these short personnel. However, this created a new problem in that they could not reach all critical overhead reaches.

The only problem tall personnel had in the UH-1H was not being able to input full lateral cyclic without having to remove their feet from the pedals. Three subjects (12, 16, and 17) experienced this problem. No recorded dimension adequately discriminated between those who did and those who

did not have this problem. The difficulty in addressing this problem is attested to by the fact that it also was experienced by one short subject (subject 3).

In the UH-60A, some short subjects were neither able to perform all critical reaches on the instrument panel nor reach all controls on the upper center console and portions of the center pedestal. Those whose total arm reach was 153 cm or more could accomplish these reaches. There were no reach-related problems associated with the foot-operated controls. No problems were encountered for tall personnel.

Short personnel did not experience any leg reach problems in the CH-47C. However, none of the short subjects could reach all critical overhead switches. The overhead switches are arranged in three fore-aft rows. All short subjects could reach the critical overhead switches in the row closest to the pilot. However, to reach all switches in the middle row and all critical switches on the row closest to the copilot (except the emergency battery switch), a total arm reach of 163 cm was needed. Two more centimeters of reach (165 cm) would allow an individual to operate the emergency battery switch as well. While not a critical problem, it is noted that two subjects (3 and 6) had to move their seats back from the full forward position to obtain full rearward movement of the cyclic. Tall personnel did not encounter any difficulties in the CH-47C.

Short personnel were the only subjects who encountered problems in the dual-piloted CH-54A. Some short subjects could not reach the rearmost laterally-oriented row of critical overhead circuit breakers above the pilot's seat. These personnel had a total arm reach <153 cm.

There were no hand-operated, control-reach problems encountered in the AH-1S. However, none of the short subjects initially evaluated could properly input full right pedal with the seat in the full up position. Only the largest of the group of short subjects, subject 6, could get the toe of his boot on the fully forward pedal with the seat in the full up position. Lowering the seat would allow personnel with a shorter crotch height to input full pedal. It was determined that personnel with a crotch height ≥ 76 cm could achieve appropriate full pedal input while still retaining a functional view of the sighting reticle which is above the glare shield in the center of the forward field of view. In the copilot's seat, the leg-reach required to input full pedal was less than that required in the pilot's seat. Tall personnel experienced no problems in the AH-1S.

Aside from the primary focus on reach-related considerations per se, data pertaining to two other helicopter-related considerations were collected during the course of the study. The first pertained to short subjects and their ability to achieve contact between their right forearm or elbow and their right thigh or knee when the right hand and right foot maintained appropriate contact with their respective controls positioned in their center positions. The second pertained to tall subjects and had to do with their ability to move the cyclic to its extreme lateral positions.

The problems observed in achieving full lateral cyclic input readily were apparent during the course of the evaluations. However, the arm-leg contact issue was one which was not so obvious. Its inclusion derived from conversations with instructor pilots. They indicated that resting their elbow or forearm on their knee or thigh provided additional stability to the arm and enhanced performance during sustained periods of flight and during operations which demand particularly fine control inputs (e.g., during slope landings and during the final 100 meters or so prior to touchdown of a "hydraulics off" landing). Additionally, an inability to rest one's forearm on the leg contributes to fatigue of the arm muscles.

The present evaluation revealed that the majority of the short subjects employed in this study could not achieve the cited arm-leg contact in the TH-55A, OH-6A, OH-58C, and UH-1H aircraft. The problem also was encountered among several short subjects in the pilot position of the AH-1S. It was observed far less frequently in the remaining helicopters: CH-47C (subject 3), CH-54A (not encountered), and UH-60A (subject 3).

Among the variables considered in separately evaluating hand-operated and foot-operated control reaches, none was effective in discriminating between those who could and those who could not achieve the arm-leg contact. So, to determine if some combination of variables could do so, the short subject measures of total arm reach and crotch height were used in conjunction with sitting height and buttock-to-knee length in a discriminant analysis for each of the aircraft where the problem was observed. For the AH-1S and the TH-55A, the classification table resulting from the analysis reflected the capability to successfully classify all subjects regarding their ability to achieve the desired contact. The loadings on standardized canonical discriminant function coefficients were highly similar for the AH-1S and TH-55A, respectively: Sitting height = +6.52 and -7.41; total arm reach = +3.53 and +3.16; crotch height = -7.55 and -9.38; and buttock-to-knee length = -1.52 and -0.56. Unfortunately, this success and

this pattern were not encountered among the other aircraft. Additionally, a somewhat puzzling finding was that one of the tall subjects, subject 14, evidenced this problem as well in all helicopters except the CH-47C and UH-60A.

As reflected in the present findings, the issue of arm-leg contact is a somewhat more difficult problem to effectively address than are the more straightforward issues of upper- and lower-reach capabilities. The lack of a precise operational definition of "adequate arm-leg contact" may be contributing to the difficulty. Too, the fact that arm-leg contact involves both upper and lower body dimensions adds to the complexity. Thigh thickness or circumference data, were they to have been available, might have assisted in the evaluation. Because multiple body dimensions likely are to be involved, to successfully address this issue likely would entail reconstituting a much larger sample of short individuals. They would be encompassing a greater range of values (perhaps up through the equivalent of the 20th percentile male in stature for some aircraft), and then obtaining measures of additional anthropometric dimensions. This would be an extension of the research program which could not be accomplished in the present effort.

The inability of tall subjects to achieve full lateral cyclic movement was observed in varying degrees in all helicopters except the CH-47C, CH-54A, and UH-60A. Among those where the problem was encountered, it was observed most frequently in the TH-55A. In it, all but two of the tall subjects evaluated experienced this difficulty. For the remaining helicopters, it was encountered with substantially less frequency; i.e., only one subject in the OH-6A, two subjects in the OH-58C and the AH-1S, and three subjects in the UH-1H.

To determine whether or not it would be possible to effectively discriminate between those tall subjects who did experience this difficulty and those who did not, a discriminant analysis was performed upon the data for each aircraft where the problem was encountered. Among the anthropometric variables measured, the following were believed to be those most likely relevant to the issue and were employed as predictor variables in the analyses: Weight, crotch height, buttock-to-knee length, and hip breadth.

The results were strikingly similar for all aircraft. In each instance, the subject's weight was by far the major discriminating variable in the analysis, weight being positively correlated with the presence of the problem. To assess the effectiveness of employing weight by itself as a discriminator, the same technique was employed as was previously used. Tall subjects were rank ordered according to

weight. Then, separately for each helicopter, all those who experienced the problem were identified. Then, each list was examined to determine the number of individuals who would have been misclassified if the weight corresponding to the heaviest individual not experiencing the problem were to have been used as the criterion weight. These weights are provided in Table 6. The results were that this procedure resulted in fewer than 5 percent misclassifications.

TABLE 6

WEIGHTS OF THE HEAVIEST SUBJECTS ENCOUNTERING NO DIFFICULTIES ACHIEVING MAXIMAL LATERAL INPUTS TO THE CYCLIC

Aircraft	TH-55A	OH-58C	UH-1H	UH-60A	CH-47C	CH-54A	AH-1S
Weight	176	223	213	243*	243*	243*	190

* No limitation encountered among subjects employed in the study. The value cited corresponds to the weight of the heaviest subject.

The use of weight as the criterion dimension to address the problem of full lateral cyclic movement in helicopters was highly successful with the sample of tall subjects employed in this evaluation. Nonetheless, because weight is a measure over which individuals can exert considerable volitional control, these data should not be employed as criteria in the same manner as either total arm reach or crotch height. Whereas a potential aviator candidate could successfully reduce his weight through a period of fasting or substantially reduced food intake, such is not the case with the linear arm and leg dimensions cited.

Furthermore, the body locations where noticeable changes in linear dimensions are most likely to be evidenced along with a change in weight (e.g., girth of waistline) are not apt to be those which will affect one's ability to achieve full lateral cyclic movement. Given these considerations, the weights cited in Table 6 would likely be most effectively employed as "signposts" or "flagging" criteria to identify those individuals for whom an actual in-the--cockpit checkout would be warranted to determine whether or not full lateral cyclic movement can, in fact, be achieved without removing one's hand from the cyclic or foot from the pedal.

Another major factor relevant to this problem is simply the lateral space available in aircraft. MIL-STD-1333A (Department of Defense 1976) focuses more upon dimensions in the fore-aft (X) and up-down (Z) directions than upon those in the left-right (Y) direction. Also, the emphasis is upon range of control movement and the relationship between the seat and the positioning of controls in what would correspond roughly to the mid-sagittal plane of an aviator. As a result, there is less precise guidance available to the aircraft designer regarding dimensions and spacing which affect the lateral movement of the arms and legs. In most cases wherein lateral cyclic movement constraints were encountered, it was the aircraft structure (e.g., unopened door) which prohibited the subject from moving his leg any further away from the cyclic.

FIXED-WING AIRCRAFT

All short subjects could reach all critical hand-operated switches, dials, knobs, etc., in the T-42A fixed-wing trainer, but those with the shorter reaches could barely do so. Not all short subjects however, were able to input full pedal. Personnel with a crotch height <71 cm experienced this difficulty. Tall personnel did not have any reach-related problems in the T-42A, but those whose sitting height exceeded 96 cm had to lean forward due to insufficient head clearance when wearing a helmet. This was not a problem when the helmet was removed.

Tall personnel did not have any difficulties in the U-8F. However, none of the short personnel could reach the following three critical circuit breakers: The 750-volt inverter circuit breaker, the landing gear circuit breaker, and the flap motor circuit breaker. All of these circuit breakers are located to the right of the copilot's yoke. Since no short subject could reach these circuit breakers, a critical length was determined by measuring the distance from the end of the reach of the largest short subject to the most distant critical circuit breaker. A total arm reach of $\geq$168 cm was determined to be necessary to effect these reaches. Another problem some short personnel had was inputting full pedal. Those with a crotch height less than 78 cm could not do so.

As in the U-8F, the flap motor circuit breaker in the U-21A is located on the copilot's side of the aircraft. Consequently, many short subjects could not reach this circuit breaker. The critical dimension for being able to reach it was a total arm reach of at least 160 cm. The only other problem encountered by personnel in the U-21A was not being able to input full pedal. Subjects with a crotch

height <76 cm could not input full right pedal. Tall personnel did not have any difficulties in this aircraft.

Tall personnel did not encounter any other difficulties in the C-12A. However, some short personnel could not input full right pedal. Those subjects with a crotch height <74 cm could not input full right pedal.

A unique problem was observed in the OV-1D. All short personnel had sufficient upper limb reaches to operate all critical hand-operated knobs, switches, dials, etc. However, some short subjects did not have enough strength to pull the shoulder harness out of the inertial reel to enable them to reach the radios in the center of the instrument panel. To tune these radios, some short subjects had to grasp the instrument panel with their left hand, pull themselves forward, and remove their right hand from the control stick, leaving the control stick unattended by either hand.

With the seat in the full up position, only personnel with a crotch height ≥75 cm could input full pedal. If the seat was lowered 6.5 cm, all short personnel could input full pedal, but then their outside visibility was extremely limited.

A problem similar to that encountered in lateral cyclic movement in helicopters was observed in two of the fixed-wing aircraft, the C-12A and OV-1D. In the C-12A, some large personnel were unable to achieve full clockwise rotation of the yoke without having to remove their right hand. In the OV-1D, some large personnel could not move the control stick fully to the right while retaining a normal grip on the handle. Unfortunately, the discriminant analyses undertaken for each of these aircraft yielded no success in being able to discriminate between those who did and those who did not have this difficulty.

SUMMARY

In response to the need to provide an empirical basis for the anthropometric criteria for US Army aviators, short and tall subjects equivalent to the lowermost and uppermost 5th percentile extremes of the Army male population were utilized to perform a static anthropometric evaluation of the soldier's (aviator's) compatibility with the cockpits of US Army aircraft. The evaluation focused on critical arm reaches and leg reaches, and on the availability of adequate head clearance. Eight short subjects ranging in stature from 146.9 cm (57.8 in) to 162.5 cm (64.0 in) and ten tall subjects ranging in stature from 182.3 cm (71.8 in) to 194.5 cm (76.6 in) were placed in the cockpits of each of the US Army's helicopters and fixed-wing aircraft. The subjects wore the clothing configuration typically employed during warm-weather training (one-piece flight suit, SPH-4 aviator's helmet, aviator's gloves, Army leather boots, and the aviator's tropical survival vest) and were asked to operate all primary controls and specified critical handles, switches, knobs, etc.

The measures most successful in discriminating between those subjects who did and did not experience upper- and/or lower-body reach difficulties were total arm reach ("span") and crotch height, respectively. Sitting height was employed to evaluate head clearance.

In general, with the exception of the UH-1H and the U-8F, all aircraft were quite compatible with the reach capabilities and sitting heights evidenced by those in the group of small subjects employed in the study.

All but four aircraft posed very minimal upper body reach demands. For most aircraft (TH-55A, OH-6A, OH-58C, UH-60A, CH-54A, AH-1S, T-42A, C-12A, and OV-1D), all but the two subjects with the shortest arm reaches in the group of short subjects (i.e., those with a total arm reach less than 153 cm) could successfully operate all critical hand-operated controls, knobs, switches, etc. For four of these aircraft (AH-1S, T-42A, C-12A, and OV-1D), the demands associated with the hand-operated controls were so minimal that the smallest subject (with a total arm reach of 147 cm) could operate all critical controls.

The four aircraft presenting the worst upper body reach demands were the UH-1H, CH-47C, U-8F, and U-21A. These required total arm reaches substantially longer than those previously listed. The demands of two of these aircraft, the

CH-47C and U-8F, could not be attained by the largest total arm reach among the short subjects in the study (163.5 cm) and had to be determined from measures extended from the end of the subject's reach capability to the location of the most distant critical reach. The total arm reaches needed for the CH-47C and the U-8F were 165 cm and 168cm respectively. The reaches for the remaining two aircraft, U-21A and UH-1H, could be attained by short subjects with total arm reaches of 160 cm and 163 cm, respectively.

Leg-reach requirements were met by at least one member of the small group in all aircraft. Crotch heights of 69-71 cm, corresponding to those of the two individuals having the shortest crotch heights in the study, were all that were required for five of the aircraft: OH-6A, UH-60A, CH-47C, CH-54A, and T-42A. Crotch heights required to attain proper pedal reaches in the TH-55A, OH-58C, UH-1H, U-21A, C-12A, and OV-1D, were in the 73-76 cm range. A crotch height of 78 cm was required for the AH-1S and the U-8F.

Head clearance problems were encountered in only four aircraft: TH-55A, OH-6A, OH-58C, and T-42A. Sitting height maximums were 96 cm, 99 cm, 97 cm, and 96 cm, respectively, for these aircraft. All other aircraft could accommodate the helmeted individual with the tallest sitting height, 102 cm, without head contact.

Observations recorded during the evaluation revealed that the largest personnel had difficulty in several aircraft achieving the full range of right-hand control inputs on the cyclic (OH-6A, OH-58C, UH-1H), yoke (C-12A), and stick (OV-1D).

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APPENDIX A

GLOSSARY

ACROMION: Highest point of the scapula.

ANTHROPOMETRY: The scientific study of the measurement of the human body.

*

BIACROMIAL BREADTH: Horizontal distance between the lateral edges of the acromial processes of the shoulder.

BUTTOCK-TO-HEEL LENGTH: Horizontal distance from the most posterior protrusion of the buttock to the bottom of the heel (measured with the subject seated, the leg extended in the same plane as the chair seat and the buttocks in contact with the back of the chair)

*

BUTTOCK-TO-KNEE LENGTH: Horizontal distance from the most posterior protrusion of the buttock to the most anterior point of the kneecap.

*

CROTCH HEIGHT: Vertical distance from floor to midpoint of crotch.

*

FOOT LENGTH: Length of foot (clothed in a wool sock) measured parallel to its long axis.

FORWARD BODY REACH: Measurement taken with the subject seated on an anthropometric measurement device. Chair seat and chair back intersect at a 90 degree angle. Subject leans forward at the waist, keeping the posterior portion of the buttock in contact with the seat back, and extends either arm on a surface above the chair seat. Reach measurement is the horizontal distance from the most posterior protrusion of the buttock to the tip of the middle finger with the subject reaching as far forward as possible.

*

FUNCTIONAL ARM REACH: Horizontal distance from a wall to the tip of the thumb. Measured with the subject's back against the wall, the right arm horizontal to the floor, and the tip of the index finger touching the pad of the thumb.

**FUNCTIONAL LEG LENGTH: Measurement taken with subject sitting erect on the edge of a chair without any back support and the right leg extended straight to a distance 5 cm above the floor. Functional leg length is the distance along the main axis of the leg from the bottom of the heel to the posterior waist landmark.

PATELLA: Knee cap

*SEATED EYE HEIGHT: Vertical distance from sitting surface to the outer corner of the eye.

**SEATED HIP BREADTH: Measurement taken with the subject sitting erect, the arms relaxed at the sides, forearms and hands extended forward horizontal to the floor, thighs supported by the sitting surface, and the long axis of the thighs parallel. Two flat surfaces are placed firmly against the thighs and the distance between the inner sides of the surfaces is measured.

*SITTING HEIGHT: Vertical distance from sitting surface to top of the head.

SHOULDER BREADTH: Horizontal distance across maximum lateral protrusions of the right and left deltoid muscles measured with the subject sitting and the upper arms against the longitudinal axis of the body.

STATURE: Vertical distance from floor to top of the head with subject wearing stockings.

TOTAL ARM REACH: Measured with the subject's back against a wall, arms extended horizontal to the floor with no bend at the elbows, fingers extended, and the palms facing outward. Arm reach is the horizontal distance from the tip of the middle finger of one hand to the tip of the middle finger of the other hand.

WEIGHT: Weight of subject wearing a flight suit with empty pockets, underwear, and stockings.

* From Churchill _et al_. (1977)
** From Churchill _et al_. (1971)

APPENDIX B

ANTHROPOMETRIC MEASUREMENTS OF SUBJECTS

ANTHROPOMETRIC MEASUREMENTS OF SUBJECTS

SUBJECT #	STATURE	MASS	SITTING HEIGHT	SEATED EYE HEIGHT	FUNCTIONAL ARM REACH	TOTAL ARM REACH	UPPER BODY REACH	SITTING HEIGHT AND FUNCTIONAL ARM REACH	SITTING HEIGHT AND TOTAL ARM REACH	BIACROMIAL BREADTH	SHOULDER BREADTH	AVERAGE FORWARD BODY REACH	FUNCTIONAL LEG LENGTH	CROTCH HEIGHT	BUTTOCK TO HEEL LENGTH	BUTTOCK TO KNEE LENGTH	HIP BREADTH	HEAD CIRCUMFERENCE
1	153.4	55.4	83.8	71.7	68.1	159.5	126.5	151.9	243.3	33.4	42.7	120.2	88.3	71.0	95.6	55.4	33.5	58.2
2	152.5	50.1	80.0	70.9	67.4	152.5	123.3	147.4	232.5	30.1	34.9	114.4	90.9	73.7	95.5	53.1	36.3	54.1
3	155.9	60.9	86.4	75.6	68.0	149.5	126.4	154.4	235.9	31.8	40.8	122.3	90.7	72.4	92.9	52.9	37.5	53.8
4	146.9	48.0	80.5	69.7	71.8	146.3	122.3	152.3	226.8	29.5	35.8	108.7	86.7	68.7	90.6	51.1	33.7	53.5
5	162.5	68.1	90.8	80.1	72.3	163.5	128.8	163.1	254.3	38.9	47.4	124.2	99.6	75.4	95.7	54.1	36.7	56.5
6	151.1	83.8	87.2	76.9	76.1	163.5	129.5	163.3	250.7	38.3	45.5	124.1	97.1	77.6	103.8	58.7	38.4	59.1
7	156.4	59.5	83.6	72.8	72.0	162.6	129.7	155.6	246.2	35.6	39.6	107.9	96.8	72.3	97.8	54.3	38.5	56.7
8	158.3	65.7	83.9	73.2	79.3	160.2	123.5	163.2	244.1	34.3	41.0	117.0	98.0	76.2	103.4	58.5	38.9	55.3
9	182.3	84.5	98.8	88.7	82.1	181.7	147.0	180.9	280.5	38.3	49.2	138.4	110.2	84.8	111.8	61.3	39.4	58.3
10	184.1	86.4	90.8	79.5	83.6	194.7	146.8	174.4	285.5	41.3	47.6	145.7	116.2	93.7	125.1	67.3	38.1	57.8
11	183.9	84.3	96.1	85.8	81.0	185.7	148.4	177.1	281.8	40.3	45.9	140.0	111.7	93.0	112.9	62.3	38.5	56.4
13	186.3	81.8	98.7	86.4	82.2	188.8	149.5	180.9	287.5	40.2	49.7	145.9	111.8	89.2	112.9	65.4	37.0	60.2
14	186.5	87.2	99.6	88.2	81.0	190.0	150.2	180.6	289.6	41.4	51.5	137.7	116.6	89.8	114.7	63.0	42.4	58.3
15	189.0	82.3	96.0	85.5	87.7	193.8	145.8	183.7	289.8	40.2	47.5	142.5	116.5	96.1	122.8	67.4	39.0	57.4
16	189.5	96.8	96.0	85.7	87.1	190.8	153.7	183.1	286.8	34.9	50.6	142.6	120.5	93.4	123.5	67.9	41.5	57.7
17	192.5	110.5	97.3	86.3	89.5	196.5	155.1	186.8	293.8	43.3	50.7	147.5	119.8	96.0	126.5	67.7	42.3	58.6
18	192.4	78.1	100.6	91.5	84.2	195.1	156.0	184.8	295.7	38.2	46.0	136.0	116.5	93.4	124.1	63.4	38.7	58.4
19	194.5	101.4	102.8	87.3	92.1	198.0	159.8	194.9	300.8	42.4	51.7	134.8	116.0	92.2	122.5	66.0	41.5	58.1

NOTE: Linear measures are expressed in centimeters; mass in kilograms.

APPENDIX C

CRITICAL ANCILLARY CONTROLS

TH-55A

INSTRUMENT PANEL
altimeter set knob

CENTER CONSOLE
all

OH-6A

INSTRUMENT PANEL
pitot heater switch
radio magnetic indicator
altimeter
bypass air caution light
radios
attitude gyro

OVERHEAD
engine device lever
cabin heat and defog lever

ELECTRICAL CONSOLE
SCAV air switch
fuel pump switch
battery switch
inverter switch
generator switch

OH-58C

INSTRUMENT PANEL
radios
clock
warning panel
attitude indicator
altimeter
fuel boost switch
caution panel

OVERHEAD
heater switch
deice switch
pitot heater switch
defog switch

UH-1H

INSTRUMENT PANEL
altimeter
clock
attitude indicator
RMI

CENTER CONSOLE
UHF navigation radio
ADF control
signal distribution panel
radios
transponder
AC circuit breakers
engine panel
hydraulic panel

OVERHEAD
hydraulics control circuit breaker
generator and bus reset circuit breaker

UH-60A

INSTRUMENT PANEL
radar altimeter
barometric altimeter
master warning panel
vertical situation indicator
horizontal situation indicator
CIS mode selector
vertical/horizontal speed indicator mode selector
liquid water content indicator
blade de-ice control panel
infrared countermeasure control panel
engine ignition switch

OVERHEAD
No. 1 and No. 2 engine fuel selector lever
No. 1 and No. 2 engine off/fire T-handle
No. 1 and No. 2 poser control lever
cockpit floodlight control
all of upper console

CENTER CONSOLE
all, including parking brake and battery/battery utility bus

CH-47C

INSTRUMENT PANEL
stick positioner
fire control handle
transmission oil temperature selector switch
transmission oil pressure selector switch
fire extinguisher agent switch

OVERHEAD
hydraulic electric power panel
fuel control panel
dome light panel
auxiliary power unit panel
flight control panel
hoist control panel

CENTER CONSOLE
all except UHF radio

CH-54B

INSTRUMENT PANEL
compass slave select switch
pilot's gyro select switch
flight direction indicator
altimeter

OVERHEAD
N1 levers
fuel shut-off levers
AC and DC circuit breaker panels
auxiliary circuit breaker panel
bypass door control
all overhead control panel switches

CENTER CONSOLE
transponder

AH-1S

INSTRUMENT PANEL
all

LEFT CONSOLE
all

RIGHT CONSOLE
all

AH-1S (copilot cockpit)
pilot override control
altimeter
gunner's control panel
TOW control panel switch
avionics
gunner electrical power switch
telescopic sight unit hand control
canopy removal arming/firing mechanism

T-42A

INSTRUMENT PANEL
static air source
landing gear control handle
mixture idle cutoff

SUBPANELS
navigation light switch
beacon light switch
fuel quantity switch
parking brake
transponder
circuit breaker panel
avionics circuit breaker panel
fuel boost pump switches
landing light switch
taxi light switch

PEDESTAL
landing lights
taxi switches

FLOOR
emergency landing gear control handle

U-8F

INSTRUMENT PANEL
attitude indicator
altimeter
clock
intercommunication box
RMI
windshield wiper control
windshield anti-ice switch
manifold pressure gauge
radios
750-volt inverter circuit breaker

SUBPANELS
defrost air control handle
landing gear circuit breaker
flap motor circuit breaker
idle cutoff switches
start selector
left and right engine alternate air control
flap handle
magneto switches
primer button
start button
inverter switches
landing light switch
pitot heat switch
prop anti-ice switch
parking brake
master switch gang bar
cabin air switch
taxi lights switch
surface deice circuit breaker
anti-ice circuit breaker

CENTER PEDESTAL
all

U-21A

INSTRUMENT PANEL
annunciator panel
transponder
radios

SUBPANELS
parking brake
inverter switch
master switch
landing lights switch
windshield anti-ice switches
emergency landing gear control handle
ignition and engine start switches
heat switches
engine ice vane control handles
flap motor circuit breaker

FUEL MANAGEMENT PANEL
all

CONTROL PEDESTAL
all

C-12A

INSTRUMENT PANEL
parking brake
landing gear handle
landing lights
dump and pressurization switch

CONTROL PEDESTAL
transponder
flap handle
control levers

OVERHEAD
emergency lights
flap motor circuit breaker
No. 1 and No. 2 engine start switches
winshield anti-ice switches
No. 1 and No. 2 inverter switches
avionics master power switch
cabin temperature mode knob
vent blower switch
aft vent blower switch
ignition and starting switches
battery generator switches
standby boost pump switches

INSTRUMENT PANEL
radios
BDHI course selector

CENTER INSTRUMENT PANEL
gear handle
emergency gear blow down handle

CONTROL PEDESTAL
control handles
emergency stores release

GLARESHIELD
fire handles

LOWER CONSOLE
all

OVERHEAD
engine no. 1 and engine no. 2 master switch
ignition buttons
generator power assist button
fuel pump switch
air conditioning control lever
generator switches
battery switches
inverter switch
weather control panel
engine crank case switch

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